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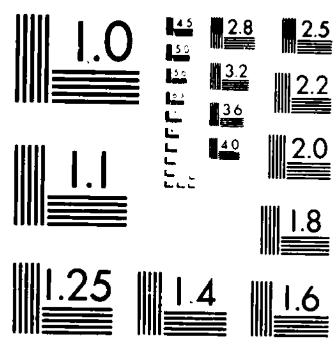

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The Field Shower Wastewater Recycling System: Development of a Program of Instruction and Preliminary Analysis of Its Potential Health Implications

by
Richard J. Scholze
John T. Bandy
William P. Gardiner
Winifred Curley
Ed D. Smith

This report discusses the development of a suggested program of instruction for operators of a Field Shower Wastewater Recycling System (FSWRS)—a system designed to recycle water used in showers in the field. The FSWRS will be used by forces deployed to Theaters of Operations located in water-short areas of the world, and will greatly reduce water supply costs. This report also identifies water quality test requirements and procedures to be used when recycling shower wastewater, and examines the health implications associated with water recycled by FSWRS.

A 40-hour training course will be sufficient to properly train a Bath Specialist in FSWRS operations. These operations will emphasize water treatment procedures and water sampling and testing. Analysis of field needs indicated that water quality testing can be limited to measurements of pH, turbidity, and residual chlorine and that these measurements can be made with relatively unsophisticated equipment.

It was found that most constituents of shower wastewater that could pose health hazards will be removed during FSWRS recycling operations. However, basic procedures should be followed, such as avoiding ingestion of recycled shower waters and ensuring that FSWRS operators take appropriate precautions in handling sulfuric acid and untreated waters. Although no health hazards are anticipated to result from components such as soaps and shampoos, there is concern about the hazard potential of volatile organic compounds, heavy metals, chlorinated compounds, and chlorination byproducts. The most likely anticipated health effects would be dermal or eye irritations.

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A 40-hour training course will be sufficient to properly train a Bath Specialist in FSWRS operations. These operations will emphasize water treatment procedures and water sampling and testing. Analysis of field needs indicated that water quality testing can be limited to measurements of pH, turbidity, and residual chlorine and that these measurements can be made with relatively unsophisticated equipment. (Cont'd)

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22b TELEPHONE (Include Area Code): (217) 373-7223

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FOREWORD

This research was conducted for the U.S. Army Troop Support Command (TROSCOM) through the Army Water Office, DALO-TSE-W, of the Office of the Deputy Chief of Staff for Logistics (ODCSLOG) under Order Number AR 2-1 (dated September 1985) and for the U.S. Air Force Engineering and Services Center (AFESC), Tyndall AFB, FL, under Job Order Number N-85-7 (dated October 1984). The investigation was performed by the Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (USA-CERL). MAJ Michael Murphy, DALO-TSE-W, and LT Al Rhodes, AFESC-RDVW, were the Technical Monitors. Acknowledgement is extended to Dr. Donald Jamison and Dr. James P. Morgan, Jr. (Virginia Military Institute [VMI] Research Laboratories), who provided assistance in preparing this report.

Appreciation is expressed to LTC McAlear, Office of the Surgeon General (OTSG) Martin Fadden, ODCSLOG, Headquarters, Department of the Army, and representatives of U.S. Army Environmental Hygiene Agency (USAEHA) and U.S. Army Medical Bioengineering Research Laboratory for their review.

Dr. R. K. Jain is Chief of USA-CERL-EN. COL Norman C. Hintz is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director. COL Roy G. Kennington is Commander of AFESC and LTC Lawrence D. Hokanson is Director of AFESC Engineering and Services Laboratory.

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THE FIELD SHOWER WASTEWATER RECYCLING SYSTEM: DEVELOPMENT OF A PROGRAM OF INSTRUCTION AND PRELIMINARY ANALYSIS OF ITS POTENTIAL HEALTH IMPLICATIONS

1 INTRODUCTION

Background

Since World War I, U.S. military operations have traditionally occurred in areas with plentiful fresh water, such as Europe and Southeast Asia. Thus, little attention was given to the availability of water supplies or sources, and especially to the need to regulate water use under field conditions. Now, however, arid regions such as the Middle East are among the likely candidates for deployment of forces. Since providing water to a military force operating in hot desert regions or water-short areas of the world is expected to be a major logistics effort, the military has directed more attention to water resource management. Water conservation, recycling, and reuse are some of the water management options being examined. Two of the largest water demands are for laundries and showers, both of which offer opportunities for recycling.

Recycling can save large amounts of water over conventional practices, particularly in water-short areas. The amount of water saved may permit troops and vehicles otherwise committed to water supply to be used elsewhere in the Theater of Operations. Recycling could also provide fuel savings and reduce other costs for water supply. The concept of recycling wastewater from showers with a simple batch system was first described in 1981.[1] Further research by the U.S. Army Construction Engineering Research Laboratory (USA-CERL) and the Virginia Military Institute (VMI) resulted in the Field Laundry Wastewater Recycling System (FLWRS) and the Field Shower Wastewater Recycling System (FSWRS). Laboratory and field testing of these systems are described in other publications.[2]

Before FSWRS can be used in the Theater of Operations, the military must first develop a set of instructions and tests for personnel who will operate the system in the field and also ensure that no health hazards are associated with use of the recycled shower water.

Operation of the FSWRS[3] involves manually adding sulfuric acid, powdered activated carbon (PAC), and cationic and anionic polyelectrolytes to wastewater collected from showers. The sulfuric acid adjusts the wastewater pH and thereby enhances

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[1] *Mathematical Modeling for Evaluation of Field Water Supply Alternatives (Arid and Semi-Arid Regions)* (Virginia Military Institute Research Laboratory, January 1981).

[2] J. T. Bandy, et al., *Development of a Field Laundry Wastewater Recycling System*, Technical Report N-86/08/ADA169585 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1986); R. J. Scholze, et al., *Testing of a Field Laundry Wastewater Recycling System* Technical Report N-87/01/A174744 (USA-CERL, 1986); R. J. Scholze, et al., *Full-Scale Test Program for a Shower Wastewater Recycling System: Technical Evaluation*, Technical Report N-87/06 (USA-CERL, 1987).

[3] J. T. Bandy, et al.; R. J. Scholze, et al., *Testing of a Field Laundry Wastewater Recycling System*; R. J. Scholze, et al., *Full-Scale Test Program for a Shower Wastewater Recycling System: Technical Evaluation.*

formation of floc-containing carbon and dirt, which accelerates settling of particles containing the adsorbed contaminants. Filtration by diatomaceous earth and disinfection with chlorine complete the treatment process. Figure 1 shows the basic configuration; further information on equipment operation and setup are provided in Appendices A, B, and C.

Objective

The objectives of this study were:

1. To develop a suggested program of instruction for operators of a FSWRS.

2. To identify the water quality test requirements, materials, and procedures to be used when recycling field shower wastewater.

3. To make a preliminary determination of the potential health implications associated with recycled shower wastewater after treatment by coagulation, filtration, and disinfection.

Approach

A suggested Program of Instruction (POI) for military operators was developed based on a "Task and Skill Analysis" of the deployment, operation, disassembly, and repacking of the proposed hardware system. The Task and Skill Analysis was performed in accordance with Army Regulation (AR) 611-101, AR 611-112, and AR 611-201.[4]

The data developed during the operational testing of the FSWRS[5] were analyzed to identify essential water quality tests the operator must perform to ensure optimum operating efficiency. The capabilities of the various components of the Water Quality Analysis Kit--Preventive Medicine were then examined to select the most appropriate test equipment for operator use.

Potential hazards associated with field use of the FSWRS were evaluated, and literature describing the health implications of chemicals expected to occur in shower wastewater was reviewed. This information was used to identify potential areas of health concern.

Mode of Technology Transfer

It is recommended that following review and approval of the FSWRS concept by the Office of the Surgeon General, Department of the Army Field Manuals 29-147, *Supply and Service, Direct Support*, and 29-114, *Field Service Company, General Support*, be amended to include guidance in the use of the FSWRS. Also, it is recommended that a Technical Manual providing operating instructions for FSWRS use be written.

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[4] Army Regulation (AR) 611-101, *Commissioned Officer Specialty Classification System* (Department of the Army [DA], 30 October 1984); AR 611-12, *Manual of Warrant Officer Military Occupational Specialties* (DA, 30 October 1984); AR 611-201, *Enlisted Management Fields and Military Occupational Specialties* (DA, 30 June 1985).

[5] R. J. Scholze, et al., *Full-Scale Test Program for a Shower Wastewater Recycling System: Technical Evaluation*.

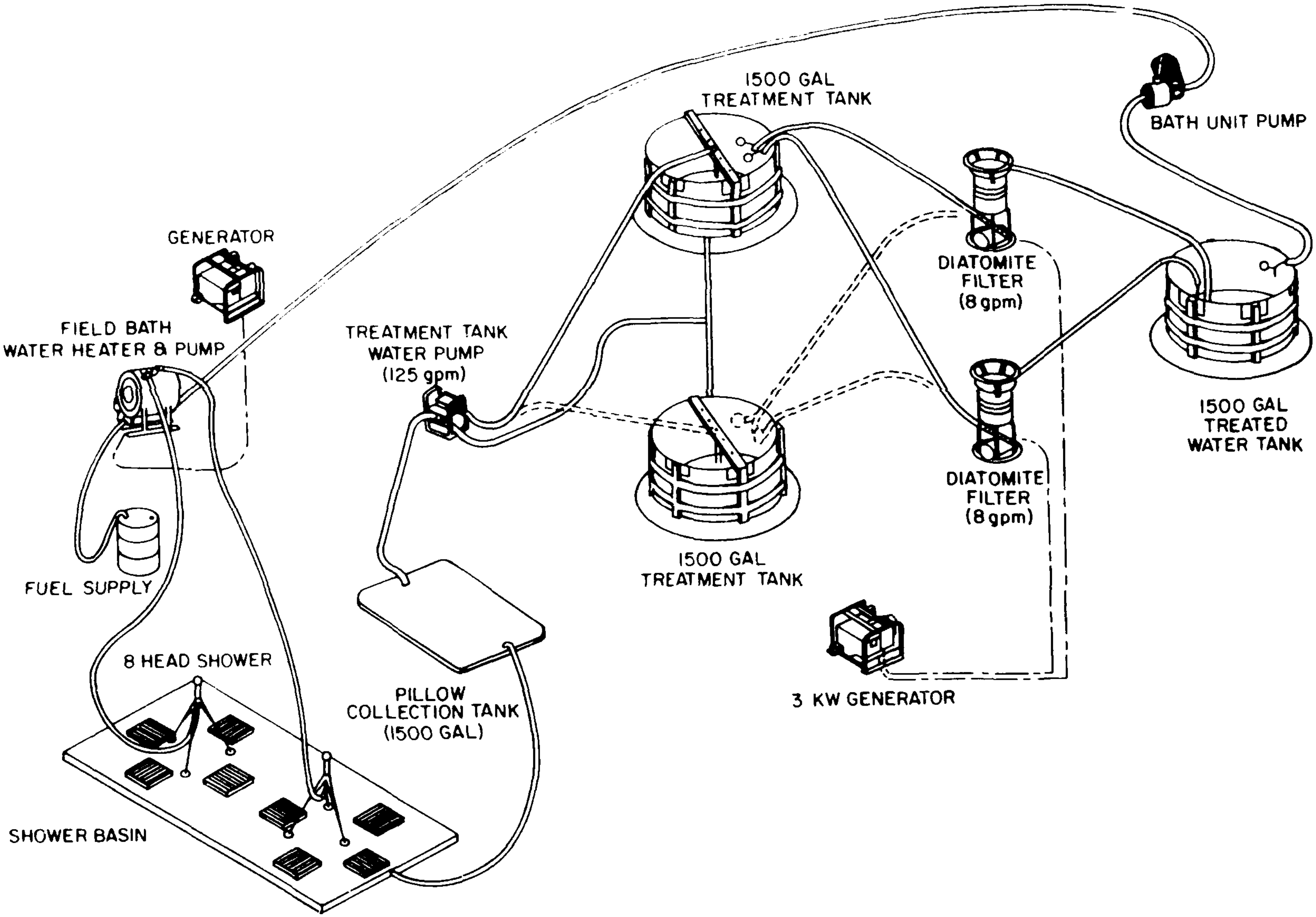

Figure 1. Field shower wastewater recycling system.

2 DEVELOPMENT OF A PROGRAM OF INSTRUCTION

A typical Bath Team, which is normally attached to a Field Service Company (General Support), consists of a Team Chief and two Bath Specialists (Appendix C). This level of staffing permits a bath facility to operate 10 hours per day, 7 days per week. One Bath Specialist is designated as driver of the cargo truck and trailer assigned to the Bath Section.

A preliminary POI was developed for Bath Specialists based on a Task and Skill Analysis (Appendix B) of the proposed field version of the shower and recycling system shown in Figure 1.

The Task and Skill Analysis was performed in accordance with Army Regulations 611-101, 611-112, and 611-201. The analysis indicated that two members of the Bath Team would be required to deploy and disassemble the FSWRS. However, only one enlisted person would be needed part-time to operate the system during a normal 10-hour shift. After the Office of the Surgeon General (OTSG) approves the system, the U.S. Army Training and Doctrine Command will determine whether it would be possible to have one member of the team operate a FSWRS in addition to normally assigned duties or whether the team must be augmented with additional personnel.

The Task and Skill Analysis in Appendix B frequently refers to a hypothetical Technical Manual on operating and maintaining the FSWRS. If the Army approves the FSWRS for troop use, such a document should be written.

Appendix A presents the suggested POI for enlisted personnel attending Advanced Individual Training for the MOS 57E, Bath Specialist. The primary focus of the instruction is on treatment procedures and water sampling and testing. Sixty-five percent of the 40 hours indicated in the POI would be devoted to Lead-Through Practical Exercises to ensure proficiency in measuring the proper amounts of chemicals, operation of the diatomaceous filter, and water sampling/testing procedures. Since students will have already become familiar with much of the equipment during classes on the deployment and operation of shower equipment, a relatively small amount of time is allotted to installation and disassembly of the system.

3 WATER QUALITY MONITORING

In previous research, the wastewater treatment techniques designed for the FSWRS were tested under laboratory conditions to validate their effectiveness.[5] A comprehensive battery of tests was performed to evaluate water quality during treatment. However, when a FSWRS is deployed under field conditions, the operator has neither the time nor the equipment to conduct similar extensive water quality testing. An evaluation of the laboratory shower test data revealed which tests could be performed readily in the field, and at the same time provide enough information to allow an operator to make operational changes to the treatment process when necessary.

The system's viability in the field hinges on whether the treatment process is providing recyclable water of appropriate quality, and the operator must know where to make adjustments when quality is not adequate. The operator can readily determine the degree of water quality by performing four simple sampling and testing procedures: two pH measurements, a residual chlorine measurement, and a turbidity evaluation. (Although care should be taken during these measurements, it is not necessary or possible to conduct tests with laboratory precision under field conditions.)

To supplement water quality test results, an operator must also observe various aspects of the treatment process described below. These observations will provide a basis for adjusting the amount of chemicals to improve both system operating efficiency and output water quality.

Water Sampling and Testing

The following sections describe the sampling and testing procedures to be performed by a Bath Specialist who operates a FSWRS. The equipment required is relatively unsophisticated water sampling and water quality testing equipment.

pH

Two separate pH measurements should be performed on each 500 gal* of shower wastewater being treated. The first is done with pH paper and involves measuring and adjusting, if necessary, the wastewater pH to ensure it is between 6.0 and 8.0 before starting the treatment process. In most cases, the colorimetric reading will indicate an alkaline condition because of the soap, dirt, and body salts from perspiration in the shower water discharge. Under these conditions, the operator incrementally adds acid (e.g., sulfuric acid) to the tank to reduce the pH to a neutral range (6.0 to 8.0), at which optimum floc is formed once the polymers and carbon are added. However, if the pH is less than 6.0, sodium carbonate (soda ash) must be added. Upon startup, several pH readings may be needed before the proper amount of acid can be determined. Thereafter, only a single reading may be needed to verify that conditions have not changed.

The second pH test, which is made on the filtered water, uses a standard color comparator equipped with pH discs. This is a more accurate measurement method than

[5] R. J. Scholze, et al., *Full-Scale Test Program for a Shower Wastewater Recycling System: Technical Evaluation.*

*Metric conversion factors are provided on p 33.

pH paper and is more appropriate for testing clean treated water, which must be in the pH range of 6.5 to 7.5 to meet OTSG standards[7] (Table 1) for direct reuse of shower wastewater for bathing. Final standards are currently being developed.

Chlorine

Treated water must be adequately disinfected before being recycled through the shower facility. Disinfection is done by adding calcium hypochlorite--a chemical available from the Army supply system.

After the calcium hypochlorite is added manually to the storage tank and thoroughly mixed with the water during the filling process, the amount of free residual chlorine is measured in the treated water storage tank. Chlorine tests are performed using a standard color comparator equipped with chlorine disks and N,N-diethyl-p-phenylenediamine (DPD) tablets.

Turbidity

Turbidity of the treated water should be measured to verify that it is less than 5 nephelometric turbidity units (NTU), as set forth in OTSG's *Interim Water Quality Standards*. A precise measurement is not required for FSWRS; therefore, use of a simple turbidimeter to determine the relative clarity of a water sample is proposed. The device recommended (see Figure 2) is currently issued with the U.S. Army's 600-gph reverse osmosis water purification unit (ROWPU) for measuring turbidity of treated water. A soldier needs only a little experience in using this device to estimate whether a 1000-mL sample of water is less or greater than 5 turbidity units.

Operational Monitoring

A Bath Specialist must periodically observe the amount of soap lather generated by bathers to assess the quality of the water being provided. Insufficient lather occurs when the wastewater has been treated a number of times, causing the calcium hardness level to build up. When this occurs, the FSWRS operator should be prepared to stop further recycling and recharge the system with fresh water.

Suspended solids normally settle quickly in the wastewater after the activated carbon and polymers are added. If settling does not occur, the operator must judge, based on visual observation, whether the wastewater has been neutralized or whether the prescribed amounts of each type of polymer need to be adjusted.

Water Quality Test Equipment

The Army has two Water Quality Analysis Sets (WQAS): one used by operators of water purification units (WQAS-Engineer) and the other by preventive medicine teams (WQAS-Preventive Medicine). These water test kits, which include the necessary reagent chemicals, are packaged in rugged, watertight cases. Each set weighs about 55 lb, contains about 4.5 cu ft, and costs more than $1000.

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[7] *Interim Water Quality Standards* (Office of the Surgeon General, 30 October 1980).

Table 1

Interim Water Quality Standards for Direct Reuse of Shower Wastewater

(From: Letter, Department of the Army, Office of the Surgeon General [DASG-PSP-E], Subject: Interim Water Quality Criteria for Shower and Laundry Reuse/Recycling [30 October 1980].)

Parameter	**Limits**
pH	6.5 to 7.5
Turbidity	<1 turbidity unit desirable <5 turbidity units permissible
Free available chlorine	5 mg/L > 20°C
	10 mg/L > 20°C
Soap hardness	Adequate sudsing

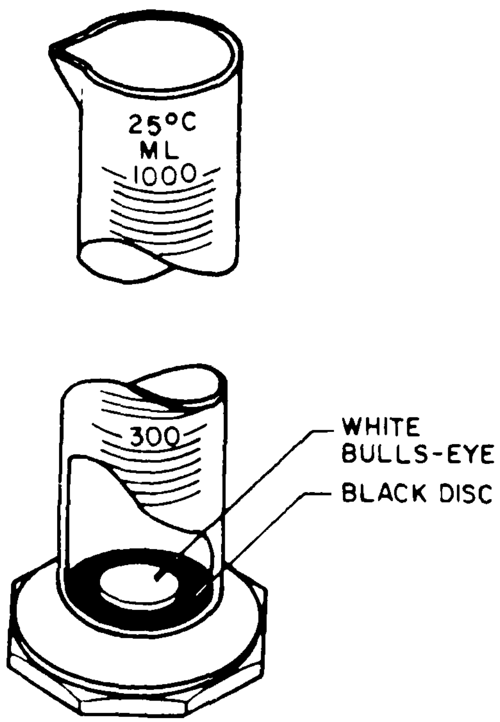

Figure 2. Field turbidimeter.

The WQAS-Engineer kit is designed to provide on-site information for determining the type of water purification equipment required, monitoring the equipment operation when installed, and detecting contamination of the water by chemicals.

The main components of the set are:

Alkalinity Test Kit
Turbidity Test Kit
Sulfate Test Kit
pH Chlorine/Residual Test Kit
Hardness Test Kit
Color Test Kit
Low-Range Chloride Test Kit
Conductivity Meter
Water Testing Kit for Chemical Agents AN-M2
Refill Kit, Chemical Detector, V-G, ABC-M30
Supporting Labware and Reagents

The WQAS-Preventive Medicine Kit is designed for on-site monitoring of the quality of raw water sources, wastewater effluents, and drinking water produced.

The main components of the set are:

Acidity Test Kit
High-Range Chloride Test Kit
Iron Test Kit
Dissolved Oxygen Test Kit
Zinc Test Kit
Multi-Purpose Spectrophotometer
    Fluoride
    Nitrogen, Ammonia
    Ferrous Iron
    Ferric Iron

The U.S. Army Belvoir Research and Development Center is currently developing water quality analysis sets to replace the two described above. However, both the old and new sets contain more test kits and equipment than necessary to monitor shower recycling operations. In lieu of standard-issue WQAS, it is recommended that only the test equipment discussed in the section on Water Sampling and Testing and listed below be provided to a Bath Team:

- pH paper, range 6.0 to 8.0
- Color comparator with pH and chlorine disks
- Turbidity tube.

A water quality analysis set containing these components should be relatively inexpensive (less than $100). More important, the simplicity of these items will enable a Bath Specialist to learn how to use them quickly and develop confidence in his/her ability to control the recycling process.

4 HEALTH IMPLICATIONS OF RECYCLING SHOWER WASTEWATER

Background

Where surface water is plentiful, as it is throughout the temperate zone, common practice is for military bath units to deploy portable bath (shower) equipment adjacent to a clean, nonpotable source of water and to use it without any treatment except heating. However, any time there are questions about the water's acceptability for use in showers, Army Preventive Medicine personnel are usually requested to evaluate the suitability of the source prior to its use. This was the typical scenario used by U.S. Army forces in the European, Korean, and Viet Nam Theaters.

Recycling shower water in areas such as those described above is not necessary and is not being considered. However, where surface sources of fresh water are scarce or nonexistent, as in hot desert regions, and where any fresh water would have to be produced from seawater or brackish waters, recycling shower water reduces costs for water, transportation, and fuel. It is in this context that shower water recycling is being evaluated. The Army currently limits bathing in a desert area to one or two showers per week. Furthermore, the amount of water used is controlled by using low-flow shower heads and by limiting a bather to a 3-minute shower. Consequently, the health implications of military personnel bathing in recycled water are evaluated here on the basis of relatively short exposure to shower water constituents. Also, tours of duty in hot desert areas would probably not exceed 12 months, which would limit exposure to recycled shower water.

The Office of the Surgeon General of the Army has considered the possibility for direct reuse of shower water in hot desert areas. The interim water quality standards for direct reuse of shower wastewater listed in Table 1 have been provided as initial guidance for agencies evaluating recycling technologies. It should also be noted that field water criteria are being revised for a large number of constituents by the U.S. Army Medical Bioengineering Research and Development Laboratory (USAMBRDL) and the Lawrence Livermore Laboratories. Their work will be incorporated in the final review of health effects, which will also include the contribution of the National Research Council's review and evaluation of health effects. It must also be noted that both the OTSG and the Water Resources Management Action Group (WRMAG) have taken the position recycle will not occur in a Nuclear, Biological, and Chemical (NBC) environment.

There is very little published information describing the occurrence and probable health effects of specific chemicals in shower wastewater. Much of the available information surveyed for this study is limited, in that specific toxicological evaluations of most potential shower wastewater constituents have not been conducted. Also, most published lists describing shower wastewater constituents provide only generalized approximations of what is likely to occur. These approximations are often based on theoretical considerations rather than actual test data.

For this study, the discussion of health implications associated with recycling shower wastewater using the FSWRS considers the following topics:

- Exposure
- Theoretical dermal risks

- Theoretical chemical composition of shower wastewater
- FSWRS purification potential.

Exposure

A worst-case evaluation of the potential adverse health effects resulting from field use of recycled shower water assumes that some contaminants remain suspended or solubilized in the shower water following treatment and disinfection. The following discussions of exposure are strictly theoretical and are based on this assumption. It should be noted that no adverse health effects were observed during full-scale tests of the FSWRS.

The primary health concern would be skin contact with chemicals remaining in the shower water following treatment and disinfection. Direct contact with some solubilized compounds could result in their being absorbed through the skin. This could cause skin irritation or systemic adverse health effects (e.g., to the nervous system). Contaminants that are not solubilized or immediately absorbed may remain on the surface of the skin. Delayed skin irritability or absorption of chemical deposits could occur during later contact with moisture, such as perspiration, rain, immersion in a lake or stream, or contact with wet ground. The pH of the moisture may also significantly affect a given compound's actual absorption or solubility.

The only anticipated risk due to inhalation exposure could result from volatile organic compounds (VOCs) remaining in recycled shower water. When the water is heated and sprayed through the shower head, the VOCs could vaporize and then be inhaled. It should be noted that VOCs are generally only very slightly soluble in water and are nonpolar. Thus, it is likely that only insignificant amounts of VOCs would escape removal by the FSWRS. Most would be absorbed by the powdered activated carbon. (Note: If VOCs are anticipated due to unusual field activities, an aeration step could be added following the diatomaceous earth filter and prior to chlorination.)

The specific chemicals present in the shower water during all phases of use or treatment may vary; however, any VOCs would be of particular concern. Those with a high vapor pressure or a high Henry's Law Constant would tend to leave the water phase and enter the air. This vaporization would be accentuated when the water is turbulent or agitated. These conditions may occur when the collected shower wastewater is transferred to the large holding or treatment tank before coagulation, and also when mixing is done during the coagulation step. This risk of respiratory exposure depends entirely on the nature of the chemicals present in the shower wastewater. It is anticipated that high vapor concentrations would be unlikely. Operating the FSWRS in a well-ventilated or unenclosed area would tend to dissipate all but the densest vapors, and preclude the use of protective breathing devices. However, the relative risk to FSWRS operators can only be determined with respect to specific compounds.

Oral exposure to contaminants present in the recycled shower water is expected to be minimal. The doctrinal effects of shower length (3 min), frequency (1/week), water quality exposure (low-flow showerheads), and tour of duty (less than 12 months) will minimize exposure to constituents. To minimize the possibility of direct ingestion of the shower water, bathers should be warned against drinking the water. Chemical and/or microbiological constituents may be present which, when concentrated by consumption of large amounts of the water, can have an impairing effect on the individual. However, these possibilities are considered to be unlikely, because filtration and chlorination should provide adequate disinfection for microbiological contaminants whereas the unit processes address chemical concerns.

FSWRS operators have a different risk of chemical exposure than the general shower field unit users. These operators would potentially have direct contact with the shower wastewater at all stages of treatment. However, the use of protective gloves and boots would minimize any additional potential health hazard associated with such direct contact. Also, use of protective equipment would prevent direct contact with the sulfuric acid used for pH adjustment during water treatment. Direct contact with this strong acid in its concentrated form can cause severe skin burns. The other water treatment chemicals used do not have similar handling hazards.

Theoretical Dermal Risks

As described earlier, the primary route of exposure to potential contaminants in the recycled shower water is through skin (dermal) contact. Information in the following sections will be based on those principles and theories of toxicology that define the potential risks of dermal exposure to contaminants in shower water. *None of the potential health problems discussed here were observed when the FSWRS was tested.* However, these health concerns could occur if sufficient contamination were encountered in the field.

In evaluating the potential of recycled shower water to cause health problems, it is important to note that response to exposure will be a function of the following factors:

- Concentration of individual chemicals in reused shower water
- Exposure time during each shower
- Duration and frequency of FSWRS use in the field.

Dermal Absorption

The skin protects the body from contaminants. Outer skin layers are made up of compact, relatively impermeable epidermal cells; however, some compounds can still be absorbed.[8] Different areas of the body have varying thicknesses of skin layers. Furthermore, absorption is inversely related to the molecular weight of the contaminant and directly related to the thickness of the epidermal layers. Consequently, since shower water contacts virtually all body parts, the opportunity for absorption through the more permeable tissues, such as the scrotum and scalp, is possible.

Absorption of chemicals through the skin can be enhanced by the following conditions:

- Elevated temperatures (e.g., heated water)
- Injury to the skin surface

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[8] H. S. Brown, D. R. Bishop, and C.A. Rowan, "The Role of Skin Absorption as a Route of Exposure for Volatile Organic Compounds (VOCs) in Drinking Water," *Am. J. Pub. Health*, Vol 74, No. 5 (1984), pp 479-484.

- Use of soaps or detergents

- Synergistic effects when several chemicals are present in the mixture.

It is anticipated that several or all of these conditions are likely to occur during field use of a FSWRS unit. Thus, chemicals present in the recycled water may be absorbed. It should again be noted that concentrations and exposure times would have to be considered before potential adverse effects could be evaluated. (Estimates of contaminant concentrations present during FSWRS use are discussed on pp 22-25.) Test experience with the FSWRS indicates that absorption of chemicals through the skin will probably not cause a significant health risk.[9]

Skin and Eye Irritations

Repeated use of shower water containing contaminant chemicals may cause skin or eye irritation. Contact dermatitis is the term generally used to describe such skin irritations. The irritation may occur as redness, a rash, dry or flaking skin, or itching and burning of the skin or eyes. The eyes are generally more vulnerable to irritation than the skin, since the epithelial layer is thin and protected only by mucus. Eye irritation resulting from shower water recycling could potentially be used as an indicator of possible contamination or the need to evaluate the recycled water. Excess chlorination or pH imbalance may be the most likely causes of skin or eye irritation when using the FSWRS.

Burrows, et al.[10] reported that concentrated synthetic shower water was found to cause skin irritation in humans and eye irritation in rabbits. Table 2 lists shower wastewater constituents that various authors have judged to pose a challenge to the recycling concept. These compounds may remain in water even after treatment. Although many of them can cause skin irritation, they probably will not at the concentrations found in the recycled water. However, the actual removal of some of these compounds with the FSWRS might be a subject for further investigation.

Some people who are sensitive to soaps and detergent may get skin irritations. Synergistic interactions of soaps and detergents with components of recycled shower water could aggravate this condition.

Allergic dermatitis, which generally is a more severe infection than contact dermatitis, could also occur following exposure to contaminants in recycled shower water. It occurs when the body produces specific antibodies against certain substances and develops an allergy to them. Once exposure has caused antibody synthesis, the person is "sensitized." Each subsequent exposure to the substance causing the allergy will then cause dermal eruptions that often increase in severity with each episode. Many people develop such a reaction to poison ivy or poison oak.

Table 3 lists compounds known to cause allergic dermatitis or dermal sensitization that may be found in shower water. Some of these compounds are also photosensitizers. Contact with these compounds cause the skin to become more sensitive or irritated upon

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[9] R. J. Scholze, et al., *Full-Scale Test Program for a Shower Wastewater Recycling System: Technical Evaluation.*

[10] W. D. Burrows, S.A. Schaub, and B.W. Peterman, "Field Reuse of Army Laundry and Shower Waters: Health Considerations," *Water Reuse Symposium III*, Vol 2 (1984), pp 973-993.

Table 2

Persistent Shower Wastewater Constituents

Compound	Concentration (mg/L)	Health Risk
Boric acid*,**	<0.2	Drying of skin
N.N-diethylene*,**	1 to 15	Eye irritant
Ethanol*	15 to 85	>10% eye irritation, chlorination reactant
Glycerol**	1 to 3	Eye irritation at high concentrations
Hexachlorophene*,**	<0.2	Damage to the myelin sheath in the central nervous system if plasma concentration >1.2 mg/L
Isopropyl alcohol*	18 to 105	>10% eye irritation; chlorination reactant
Isopropyl myristate*,**	<0.2	Hyperketosis may develop with continued use
Lactic acid*	5	Chlorination reactant
Oleic acid*,**	16 to 50	Mild skin irritant
Propylene glycol*	0.3	Weak eye irritant; chlorination reactant
Sodium carbonate*	450	Eye irritant (concentrated solution)
Sodium chloride*	60 to 80	Eye irritation (>1% solution)
Sodium tripolyphosphate**	5 to 11	Skin and eye irritant
Triethanolamine*,**	1 to 5	Skin and eye irritant
Urea*	1 to 3	Chlorination reactant

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*D. R. Cogley, W. Foy, W. G. Light, J. C. Eaton, and M. Mason, "Evaluation of Health Effects Data on the Reuse of Shower and Laundry Waters by Field Army Units," *Proceedings Water Reuse Symposium*, Vol 3 (1979a), pp 2252-2268.

**D. R. Cogley, W. Foy, W. G. Light, J. C. Eaton, and M. Mason, *Evaluation of Health Effects Data on the Reuse of Shower and Laundry Waters by Field Army Units*, Walden Division of Abcor, U.S. Army Medical Research and Development Command (USAMBRDL), Contract No. DAMD 17-78-C-8057 (USAMBRDL, April 1979b).

Table 3

Compounds Causing Dermal Sensitization

Compound*	Use**
Nickel	Alloys such as stainless steel, alkaline storage batteries, magnets
Protease	Meat tenderizers, some detergents
Parabens	Antimicrobials in food and drugs
Lanolin	Ointments, soaps, sun lotions
Propylene glycol	Antifreeze, solvents, hydraulic fluids, sun lotions, brake and deicing fluids, bactericide
Triethanolamine	Dry cleaning solutions, soaps, detergents, water repellent, softening agent
Sorbic acid	Fungicide, food preservative
Hexachlorophene	Germicidal soap, veterinary medicine
Neomycin***	Antibacterial salves and creams
Benzocaine***	Topical anesthetics

*D. R. Cogley, W. Foy, W. G. Light, J. C. Eaton, and M. Mason, "Evaluation of Health Effects Data on the Reuse of Shower and Laundry Waters by Field Army Units," *Proceedings Water Reuse Symposium*, Vol 3 (1979a), pp 2252-2268; D. R. Cogley, W. Foy, W. G. Light, J. C. Eaton, and M. Mason, *Evaluation of Health Effects Data on the Reuse of Shower and Laundry Waters by Field Army Units*, Walden Division of Abcor, U.S. Army Medical Research and Development Command (USAMBRDL), Contract No. DAMD 17-78-C-8057 (USAMBRDL, April 1979b).

**G. G. Hawley, ed., *The Condensed Chemical Dictionary*, 10th ed. (Van Nostrand Reinhold Co., 1981).

***S. D. Prystowski, A. M. Allen, R. W. Smith, J. H. Nonomura, R. B. Odom, and W. A. Akers, "Allergic Contact Hypersensititity to Nickel, Neomycin, Ethylenediamine, and Benzocaine," *Arch. Dermatol*, Vol 115 (1979), pp 959-962.

exposure to sunlight. The occurrence and/or removal of the compounds listed in Table 3 with the FSWRS may warrant further investigation.

The minimal health risk potential from the use of recycled shower wastewater is supported by the absence of any dermal irritations in bathers who participated in the laboratory test program (see Figure 3). Each of the 19 people who signed affidavits certifying their lack of dermal irritations took at least 25 showers in recycled water; this amount reflects about 55 percent of the showers taken during the test.

Skin Cancer

It is unlikely that contact with recycled shower water would cause epithelial cell mutations leading to skin cancer. None of the chemicals judged likely to remain in treated water have been epidemiologically associated with skin cancers. Also, standard assays[11] show concentrated synthetic shower water solids to be nonmutagenic.

Microbial Infections

Recycled water of any type poses a potential disease risk if infectious microorganisms survive the treatment. However, it is unlikely that any infectious microorganisms will survive chlorination and diatomaceous earth filtration. One possible exception could be some types of viruses. Laboratory results[12] for coliform testing on FSWRS water indicate that the system effectively eliminates bacterial populations of concern. However, viruses, including adenovirus, reovirus, echovirus, poliovirus and coxsackie virus A and B, have been found in high-quality wastewater not associated with the FSWRS.[13] Polio is an illness of the central nervous system. The rest of the viruses are generally associated with gastrointestinal and respiratory illnesses following oral exposure to the appropriate organism. However, exposure to any viruses in recycled FSWRS shower water would probably be dermal. This would minimize the potential health risks. Further laboratory testing should be undertaken to determine if viruses occur in recycled FSWRS water and what specific strains and concentrations may warrant health risk concerns.

Theoretical Chemical Composition of Shower Wastewater

Detailed chemical analysis of FSWRS recycled shower water was not carried out for this study. However, in evaluating the potential health risks associated with shower water reuse, the theoretical occurrence of various contaminants must be considered. The following sections will discuss the available published literature on shower wastewater content, with particular emphasis on military-related experience or studies. It should be noted that none of the individual chemicals discussed have been identified as actually being either present or absent in shower water before or after FSWRS treatment.

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[11] W. D. Burrows, S. A. Schaub, and B. W. Peterman.

[12] W. D. Burrows, S. A. Schaub, and B. W. Peterman.

[13] J. L. Riggs and D. P. Smith, *Viruses in Water and Reclaimed Wastewater*, EPA-600/S1-83-018 (U.S. Environmental Protection Agency, March 1984).

SUBJECT: Shower Wastewater Recycling Research Project

TO: Donald K. Jamison, Project Director

I participated in the Shower Wastewater Recycling Project sponsored by the VMIRL and the Department of Civil Engineering during the summer of 1985.

At no time during or since I stopped showering in the recycled water have I experienced any skin irritation, rash or any other dermal problems that I would associate with this project.

____

Signature

Figure 3. Bather affidavit.

Contaminants

Army field conditions do not restrict the types of cosmetic and health care products a soldier uses. Work assignments and field activities also vary, so the types of body soil and "occupational dirt" carried by soldiers differ. Thus, the theoretical composition of shower wastewater is complex, and any single wastewater sample may easily contain a broad spectrum of waste components. Table 4 shows a generalized picture of shower wastewater. This profile integrates information from a USAMBRDL list of the types of products present in shower water after a single use, with composition data for various commercial personal hygiene products.[14] Again, identification and measurements of these specific compounds was not done for FSWRS waters.

The constituents listed in Table 4 can be placed into six categories of origin:

- Soaps, shampoos, and other toiletries used in the showering process
- Topically applied cosmetic and health care products, such as antiperspirants, aftershave lotions, sun screen preparations, and insect repellents
- Shower cleaning products (not applicable to FSWRS)
- "Occupational dirt" and body soil
- Human epithelial cells, hair, bacteria, and viruses
- Accidental contaminants of human orgin (urine, feces, saliva, vomitus).

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[14] D. R. Cogley, et al., *Evaluation of Health Effects Data on the Reuse of Shower and Laundry Waters by Field Army Units*, Walden Division of Abcor, U.S. Army Medical Research and Development Command (USAMBRDL), Contract No. DAMD 17-78-C-8057 (USAMBRDL, April 1979b).

Table 4

Shower Wastewater Constituents

	mg/L
Silica flour	100 - 210
Sodium chloride	60 -180
Castor oil	20 - 130
Isopropyl alcohol	18 - 105
Ethanol	15 - 85
Kaolinite	20 - 50
Oleic acid	16 - 50
Talc	41
Tallow	13 - 38
Stearic acid	11 - 31
Coconut oil	9 - 30
Castor oil, sulfonated (75%)	6 - 30
Ultrawet 60-L	5 - 25
Ammonium lauryl sulfate	5 - 25
Sodium lauryl sulfate	5 - 22
Epithelium cells	18
N,N-diethyl-m-toluamide	1 - 15
Sodium dodecylbenzenesulfonate	3 - 13
Sodium tripolyphosphate	5 - 11
Olive oil, sulfonated (75%)	2 - 10
Tannic acid	1 - 8
Triethanolamide alkylbenzene sulfonate (60%)	1 - 7
Potassium oleate (20%)	1 - 6
Kaolin, colloidal	5
Lactic acid	5
Triethanolamine	1 - 5
Urea	1 - 3
Glycerol	1 - 3
Potassium hydroxide	0.7 - 3
Zinc stearate	3
Coconut diethanolamine (92)	0.5 - 3
Hair	2
Mineral oil	0.5 - 2
Potassium	1.5
Calcium carbonate	0.9
Aluminum hydroxide	0.9
Sorbitol	0.7
Dicalcium phosphate	0.6
Sodium-ortho-phenylphenolate	0.6
Sodium-4-chloro-w-phenylphenolate	0.5
Sodium metaphosphate	0.4
Aluminum formate solution	0.4
Propylene glycol	0.3
Volatile silicone	0.2
Tegacid	0.2
Aluminum chlorhydrate	0.2
Tween 80	

The following compounds are present at <0.2 mg/L

Alumina
Aluminum chloride
Aluminum sulfate
Ammonium alum
Beeswax
Boric acid
Cetyl alcohol
Corn starch
Bentonite
Hexachlorophene
Isopropyl myristate
Jamaican rum
Magnesium carbonate
Magnesium oxide
Glycerol monostearate
Methyl paraben
Lanolin
Petrolatum
para-Aminobenyoic acid (PABA)
Isopropyl palmitate
Polyethylene sorbitan monostearate
Saccharin sodium
Sodium-5-chloro-2-phenyl-phenolate
Sodium hydroxide
Sorbitol
Spermaceti
Sorbitan monostearate
Stannous fluoride
Veegum
Zinc chloride
Sodium stearate

Ingredients from the first two categories predominate in shower wastewater (Table 4). Shower cleaning products would not be found in FSWRS shower wastewater, since this system does not have to be cleaned. The latter two groups of waste constituents are expected to be very minimal, and the occupational dirt contacted will vary with the type of field activity. However, the main sources of potentially hazardous substances in recycled shower water are likely to be from these two groups.

Most of the constituents listed in Table 4 are organic. Their general presence in wastewater can be monitored by measuring total organic carbon (TOC). The TOC values in the FSWRS-treated wastewater increase significantly in comparison to the source water.[15] However, TOC drops significantly with water treatment, which indicates that FSWRS is efficient in removing organic compounds.

Shower wastewater also contains inorganic compounds. Their presence in FSWRS-treated wastewater is reflected by measuring hardness and total dissolved solids. Changes in these measurements during wastewater treatment also reflect the efficacy of the FSWRS process. Available data indicate that many of these compounds are not removed during FSWRS treatment,[16] but that the adverse health effects they would cause would be negligible.

Table 5[17] compares the chemical composition of shower wastewater with that of tapwater. The parameters for field shower wastewater and tapwater listed in the table can serve as guidelines for evaluating the FSWRS water treatment process.

Water Treatment Chemicals

The chemical composition of shower wastewater is also affected by the chemicals added during the recycle/reuse treatment phase. The following chemicals are added:

- Polymer Type I, a cationic coagulant (Cat-Floc produced by Calgon Corp.)
- Polymer Type II, an anionic coagulant (Hercofloc 1018 produced by Hercules, Inc.)
- Sulfuric acid for pH adjustment
- Soda ash (anhydrous sodium carbonate) for pH adjustment
- Powdered activated carbon to absorb organic components
- Calcium hypochlorite for disinfection.

R. J. Scholze, et al., *Full-Scale Test Program for a Shower Wastewater Recycling System: Technical Evaluation.*
R. J. Scholze, et al., *Full-Scale Test Program for a Shower Wastewater Recycling System: Technical Evaluation.*
L. K. Wang, *Characterization Studies of Wastewater Generated from Military Installations*, Calspan Report No. ND-5296-M-1 (U.S. Army Mobility Equipment Research and Development Center, August 1972).

Table 5

Characteristics of Field Shower Wastewater and Related Tapwater
(From: U.S. Army Mobility Equipment Research and Development Center)

Parameter (mg/L Except as noted)	Chemical Analysis	
	Shower Wastewater*	**Tap Water***
Turbidity, JTU	59.0	0.34
pH, unit	6.8	7.9
Total dissolved solids	175.0	135.0
Detergent	1.75	0.04
Total phosphate	35.0	20.0
Ortho phosphate	28.0	12.0
Poly phosphate	7.0	8.0
Sulphate	22.0	22.0
Silicate	55.0	36.0
Total hardness ($CaCO_3$)	18.0	12.0
Calcium hardness ($CaCO_3$)	16.0	12.0
Magnesium hardness ($CaCO_3$)	2.0	0.0
Total alkalinity	136.0	108.0
Chloride	10.0	10.0
BOD, 5-day	51.0	--
TOC**	15.0	--

*All parameters except TOC were analyzed on 2 August 1972.
**TOC of the shower wastewater was analyzed on 28 August 1972.

It is anticipated that exposure to these chemicals in the appropriate concentrations will not adversely affect health. Both coagulant polymers are approved by the U.S. Environmental Protection Agency for use in drinking water systems. Their formulations and recommended doses do not result in residuals or contaminants of concern.

The use of sulfuric acid will add sulfate to the wastewater; however, the amounts of sulfate do not approach unhealthful levels, so field operators need not monitor this parameter. Similarly, use of soda ash will increase the carbonate content of the shower wastewater; however, this parameter does not require monitoring in the field because increased hardness and resultant low sudsing will reflect any high carbonate concentrations. Also, there is no information to indicate that dermal exposure to sulfates or carbonates is hazardous.

Powdered activated carbon, along with anything adsorbed to those particles, is removed from the FSWRS processed water by settling and diatomaceous earth filtration. Monitoring of turbidity (frequency to be suggested by the field operating procedures) will detect any breakdown of the settling and filtering process. Inadequate clarification could result in increased skin irritation from carbon particles.

Calcium hypochlorite is manually added to the filtered water and allowed to react for 30 minutes before the water is used. The amount of calcium hypochlorite required is based on field tests of residual chlorine. Testing ensures that chlorine levels are maintained within the range that maximizes antimicrobial activity yet does not present a human health hazard. Excessive chlorine in water tends to irritate both skin and eyes.

FSWRS Purification Potential

The FSWRS treatment process consists of three phases:

- Coagulation and adsorption to powdered carbon followed by sedimentation
- Diatomaceous earth filtration
- Disinfection by chlorination.

Each phase contributes to the removal of several types of contaminants, as described in the following sections.

Nonpolar Organic Compounds

Adsorption to powdered carbon is expected to remove nonpolar organics from the shower wastewater. Particulate matter such as talc and kaolin, plus any substances adsorbed to particulate surfaces would be removed, at least partially, with settlement of the floc produced by the coagulant aids.

Polar Organic Compounds

Soluble polar organic compounds are removed during the coagulation/adsorption/sedimentation process. To provide an example for evaluation, Table 6 lists the theoretical adsorption capability of activated carbon for potential polar organic shower water constituents.

Treatment with activated carbon only partially removes these compounds from shower wastewater. They are therefore the most likely type of shower wastewater constituents to remain and are good candidates for further study about health effects of FSWRS use.

Inorganic Compounds

Soluble inorganic compounds tend not to be completely removed during treatment. However, concentrations do seem to plateau with late cycles, which may represent solubility limits for selected inorganics. There is also a practical limit on the concentration of many ions in recycled shower water; as hardness increases, suds formation is reduced. Recycled water that will not form suds is unsuitable for shower use.

No significant health ris. from most of the inorganics found in the recycled shower water is anticipated. Phosphates, sulfates, carbonates, calcium, magnesium, and others have not been shown to cause skin irritation. The only anticipated risks would be due to heavy metals, and these are unlikely to occur. Nickel was listed in Tab'e 3 as causing dermal sensitization. However, nickel accumulation can probably be avoided as long as standard Army fabric tanks and hoses are used in the FSWRS rather than stainless steel equipment.

Table 6

Theoretical Adsorption of Activated Carbon

Shower Water Constituent	**Amount Adsorbed (%)**
Ethanol	10
Glycerol	25
Isopropyl alcohol	40
Lactic acid	60
Potassium oleate	80
Propylene glycol	35
Sorbitol	75
Triethanolamine	70
Urea	5

Suspended Solids and Infectious Microorganisms

Suspended particulates and substances adsorbed to their surfaces would be removed by diatomaceous earth filtration.[18] Bacteria, viruses, protozoan cysts, parasitic eggs and larvae would also be partially removed in this process.[19] It is likely that any infectious microorganisms remaining in the shower wastewater after diatomaceous earth filtration would be killed by chlorine disinfection.

The antimicrobial efficacy of chlorination depends on the concentration and form of chlorine used, contact time, and pH. Studies indicate that the hypochlorous ion is the most effective disinfectant in shower wastewater treatment, and that the hypochlorite ion is the next most effective.[20]

Unfortunately, chlorination can also chemically modify the polar organics remaining in the treated water.[21] The concentrations of some of the chlorinated compounds, where formation is related to individual reaction kinetics, the hypochlorite ion, and precursor concentrations,[22] may pose a risk to health. These compounds are discussed in the following section.

Chlorination Byproducts

Table 7 gives expected chlorination reaction products for ethanol, isopropyl alcohol, urea, lactic acid, triethanolamine, and propylene glycol. Of these compounds,

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[18] D. R. Cogley, et al., "Evaluation of Health Effects Data on the Reuse of Shower and Laundry Water by Field Army Units," *Proc. Water Reuse Symposium*, Vol 3 (1979), pp 2252-2268.

[19] *Drinking Water and Health* (National Academy of Sciences, 1977); J. D. Gensler, *Interim Water Quality Criteria for Shower and Laundry Reuse/Recycle*, DASG-PSP-E (OTSG, 30 October 1980).

[20] J. D. Gensler.

[21] D. R. Cogley, et al., "Evaluation of Health Effects Data on the Reuse of Shower and Laundry Water by Field Army Units."

[22] D. R. Cogley, et al., "Evaluation of Health Effects Data on the Reuse of Shower and Laundry Water by Field Army Units."

Table 7

Chemicals Formed by Chlorination

Precursor	**Chlorinated Byproduct**
Ethanol	$Cl\text{-}CH_2\text{-}CH_2\text{-}OH$ 2-chloroethanol (ethylene chlorohydrin)
Isopropyl alcohol	$Cl\text{-}CH_2\text{-}CH\text{-}CH_3$ OH 1-chloro-isopropyl alcohol
Urea	O O $Cl\text{-}HN\text{-}C\text{-}NH_2$, $Cl_2\text{-}N\text{-}C\text{-}NH_2$ mono and di-N-chloroamides
Lactic acid	O $CH_3\text{-}CH\text{-}C$ Cl OH acid chloride O $Cl\text{-}CH_2\text{-}CH\text{-}C$ OH OH chloro acid
Triethanolamine	CH_2CH_2OH $Cl\text{-}N\text{-}CH_2CH2$ diethanolchloroamine
Propylene glycol	$Cl\text{-}CH_2\text{-}CH\text{-}CH_2$ OH OH 3-chloro propylene glycol

only the 2-chloroethanol (ethylene chlorohydrin) appears to be a possible health hazard. The health concerns associated with 2-chloroethanol are:

- High inhalation toxicity (2 ppm per 1 hour was fatal to rats[23])
- Rapid skin adsorption from water solution[24]
- Severe skin and eye irritant upon exposure[25]
- Mutagen and possible carcinogen.[26]

Accordingly, even trace amounts of 2-chloroethanol may present a serious health hazard.

Given a precursor concentration of 100 ppm, an estimated maximum of 25 ppm 2-chloroethanol can be produced.[27] Actual concentrations of 2-chloroethanol would be limited by chlorine concentration. The estimated concentration of ethanol in shower wastewater is 15 to 85 ppm.[28]

To determine the potential accumulation of chlorinated hydrocarbons during the continuous recycling of treated and chlorinated shower water, USAMBRDL analyzed various samples by gas chromatography and mass spectroscopy (GC/MS).

Results indicated that estimated concentrations of individual trace organics ranged from <0.1 ppb to 10 ppb, with most below 1 ppb. The total trace organic content of the treated waters appeared to decrease with the increasing number of treatment cycles given each batch: cycle 1 was equivalent to source water, cycle 4 somewhat cleaner, and cycles 8 and 11 were cleaner still. The results indicated that actual use of the FSWRS poses little if any health risk from chlorination byproducts created during disinfection. Appendix D presents the USAMBRDL findings.

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[23] D. R. Cogley, et al., "Evaluation of Health Effects Data on the Reuse of Shower and Laundry Water by Field Army Units."

[24] D. R. Cogley, et al., "Evaluation of Health Effects Data on the Reuse of Shower and Laundry Water by Field Army Units."

[25] National Institute of Occupational Safety and Health, *Registry of Toxic Effects of Chemical Substances* (U.S. Department of Health and Human Services, July 1985).

[26] *Registry of Toxic Effects of Chemical Substances.*

[27] D. R. Cogley, et al., "Evaluation of Health Effects Data on the Reuse of Shower and Laundry Water by Field Army Units."

[28] D. R. Cogley, et al., "Evaluation of Health Effects Data on the Reuse of Shower and Laundry Water by Field Army Units."

5 CONCLUSIONS AND RECOMMENDATIONS

The FSWRS is made up of hardware components already in the Army supply system, is easy to deploy, and should be capable of being operated by properly trained enlisted Bath Specialists (MOS 57E).

A 40-hour training course would be sufficient to properly train a Bath Specialist to become a capable FSWRS operator.

Only one Bath Specialist is required to operate a FSWRS; with more experience in FSWRS operations, an operator may also have time to perform other duties.

Relatively unsophisticated water sampling and water quality testing equipment can be used to control the wastewater treatment process. Testing can be limited to measurement of pH, turbidity, and residual chlorine.

Safety procedures must be observed to avoid personal injury when handling sulfuric acid and to avoid extended dermal contact with or ingestion of shower wastewater.

No health hazard is anticipated to result from the use of soaps, shampoos, body oils and water treatment chemicals during FSWRS operations. Chemicals identified as contaminants of potential concern if they remain in treated water include volatile organic compounds, viruses, soluble polar organic compounds, heavy metals, chlorinated components, and chlorination byproducts.

The primary source of potentially hazardous substances in recycled shower waters is anticipated to be body soil and/or excretions.

The most likely anticipated type of adverse health effect to occur using recycled FSWRS shower water would be dermal or eye irritations. However, for adverse effects to occur, chemicals causing these irritations would have to persist in greater than threshold concentrations after FSWRS treatment.

No adverse health effects of any kind were experienced by shower bathers during and after testing of FSWRS operations. VOC concentrations are successively reduced with each recycle to below source levels and do not tend to remain in FSWRS recycled water.

The short-term and limited duration of exposure to recycled shower water by bathers in a Theater of Operations situation should minimize health risks from FSWRS use.

The quality of recycled water achieved with a FSWRS unit is consistent, and is anticipated to be superior or at least equal to any untreated surface waters available for bathing in the Theater of Operations.

The U.S. Army Training and Doctrine Command (TRADOC) should review the adequacy of the Task and Skill Analysis Report and the suggested Program of Instruction for a FSWRS operator.

A full-scale field testing of a FSWRS should be conducted that includes analysis of the persistence and/or occurrence of dermally irritating compounds, identified in previous military literature as occurring in recycled shower water. More comprehensive evaluation should also be performed for chemical and microbiological contaminants at both laboratory scale and field testing.

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METRIC CONVERSION FACTORS

1 gal	=	3.785 L
1 lb	=	0.4535 kg
1 cu ft	=	0.0283 m^3
1 in.	=	25.4 mm
1 ft	=	0.3048 m
1 psi	=	6.985 kPa

APPENDIX A:

PROGRAM OF INSTRUCTION FOR OPERATION AND OPERATOR MAINTENANCE OF A FIELD SHOWER WASTEWATER RECYCLING SYSTEM

SECTION I. PREFACE

A. Course:	Operation and Operator Maintenance of a Field Shower Wastewater Recycling System (FSWRS) - Proposed.
B. Purpose:	To provide enlisted personnel with the required knowledge and skills to deploy and operate the FSWRS, and to perform Operator Maintenance.
C. Prerequisite:	Assignment as instructor or operator of a field bath unit.
D. Length:	Peacetime--5 days.
E. Training Location	To be determined.

F. MOS Feeder Pattern:	Prerequisite MOS	MOS trained in this course.
	Operator 57E	Same as prerequisite.

G. Ammunition Requirement:	No ammunition required.

SECTION II. SUMMARY

Course:	Operation and Operator Maintenance of a Field Shower Wastewater Recycling System (FSWRS)--Proposed.
Hours:	40

		Hours	Annex
A. Academic Subjects:	Operation and Operator Maintenance	40	A
B. Nonacademic Subjects:	Not applicable.		
C. Recapitulation:			
	Type of instruction:		
	Conference	11	
	Lead-Through Practical Exercise	25	
	Examinations	4	

SECTION III. BODY

Course: Operation and Operator Maintenance of a Field Shower Wastewater Recycling System (FSWRS)--Proposed.

Academic Subjects: 40 hours

Annex Title and Subjects	Hours	Annex
Operation and Operator Maintenance		A
Introduction to Course, Operation, and Operator Maintenance	2	A
Deployment of FSWRS	3	A
Operation and Maintenance of FSWRS	29	A
Disassembly and Stowing of FSWRS	2	A
Performance and Written Examination	4	A
Total Annex:	40	

SECTION IV. ANNEXES

Annex A: Operation and Operator Maintenance

Purpose: To provide the student with the required course objectives, performance standards, publication references, equipment and component descriptions to operate and maintain the FSWRS at the Operator level.

File No.	Classification	Type of Instruction
FSWRS-A-010-010	Introduction to Operation and Operator Maintenance	
Hours: 2	U	2C

Objective: In a training environment, given course material referenced technical manual, and the FSWRS, the student will:

(a) Identify referenced publications and state their applications in this lesson.

(b) State the purpose, capabilities, features, and technical principles of operation.

(c) Identify the components and their function and location in the system.

(d) Relate the components of the FSWRS to the technical manual reference.

Completion of tasks will be verified by an instructor as specified in technical manual reference.

References: Technical Manual on FSWRS.

Note: U unclassified; C = conference.

File No.	Classification	Type of Instruction
FSWRS-A-010-020	Deployment of FSWRS.	
Hours: 3	U	lC, 2 LTPE

Objective: At a field operating site, given a disassembled but otherwise fully operable FSWRS, the necessary tools and materials, technical manual, and a student workbook, the student will:

(a) Assemble the FSWRS.

(b) Identify the components of the system.

(c) Identify key features of each component.

(d) Perform preventive maintenance checks and services on the FSWRS.

References: Technical Manual; Student Workbook.

Note: U = unclassified; C = conference; LTPE = lead-through practical exercise.

File No.	Classification	Type of Instruction
FSWRS-A-010-030	Operation and Maintenance of the FSWRS	
Hours: 29	U	8C, 21 LTPE

Objective: At a field operating site, given a fully assembled and operational FSWRS and Technical Manual, the student will:

(a) Perform preventive maintenance checks and services on the FSWRS.

(b) Operate the FSWRS.

(c) Perform water sampling and testing procedures.

(d) Perform troubleshooting on the FSWRS.

(e) Perform the FSWRS diagnostic program.

(f) Perform operator maintenance on the FSWRS.

Performance and completion of tasks will be verified by an instructor.

References: Technical Manual; Student Workbook.

Note: U = unclassified; C = conference; LTPE = lead-through practical exercise.

File No.	Classification	Type of Instruction
FSWRS-A-010-040	Disassembly and Stowing of FSWRS	
Hours: 2	U	2 LTPE

Objective: At a field training site, given an assembled FSWRS, the student will:

(a) Disassemble and prepare the FSWRS for movement to another operating location.

(b) Prepare the FSWRS for storage.

Performance and completion of tasks will be verified by an instructor as specified in the Technical Manual.

References: Technical Manual; Student Workbook.

Note: U = unclassified; LTPE = lead-through practical exercise.

File No.	Classification	Type of Instruction
FSWRS-A-010-050	Performance and Written Examinations	
Hours:	4	U4 EI

Objective: In a training environment, given a fully assembled and operational FSWRS, the student will:

(a) Identify key features of the technical manual and the features' application.

(b) Demonstrate knowledge of the purpose, capabilities and features of the FSWRS.

(c) Demonstrate knowledge of technical principles of operation.

(d) Identify components and their location on the FSWRS and in the manual.

(e) Perform preventive maintenance checks and service tasks and procedures.

(f) Conduct one complete treatment cycle using the FSWRS.

The student will demonstrate knowledge and perform the above tasks without error in accordance with Technical Manual. The student's performance will be evaluated by an instructor using the references listed below.

References: Technical Manual; Written Instructions.

Note: U = unclassified; EI = examination.

APPENDIX B:

TASK AND SKILL ANALYSIS—FIELD SHOWER WASTEWATER RECYCLING SYSTEM

SECTION I: SYSTEM/EQUIPMENT

A. Operation and Maintenance Concept

1. Operation: The Field Shower Wastewater Recycling System (FSWRS) will be operated by bath teams in semiarid regions or other areas where natural water sources are scarce. By collecting, treating, and recycling the wastewater from the field bath units, the FSWRS will greatly reduce the amount of fresh water that will have to be carried by truck to bath unit locations.

2. Maintenance: All FSWRS components are already in the Army inventory within various water treatment and distribution systems. Thus, no new or different maintenance procedures or concepts will be required to support fielding of the system.

B. General System/Equipment Description

The FSWRS consists of a wastewater collection tank, wastewater transfer pump, wastewater treatment tanks (two each), diatomite filter units (two each), generator set, shower water storage tank, miscellaneous hoses, valves, and fittings (Figure 1). The function of each major component is discussed below.

1. Wastewater Collection Tank: Receives and stores wastewater discharged by the Field Bath Units.

2. Wastewater Transfer Pump: Transfers wastewater from the wastewater collection tank to the wastewater treatment tank and recirculates it through the treatment tank during the coagulation process.

3. Wastewater Treatment Tank: Serves as a recirculation and storage vessel during the coagulation and sedimentation processes.

4. Diatomite Filter Unit: Filters the treated wastewater and transfers it from the treatment tank to the shower water holding tank.

5. Generator Set: Provides electric power to the filter unit.

6. Shower Water Storage Tank: Receives and stores fresh water obtained from a field water point and recycled wastewater for use by field bath units.

C. Government Furnished Equipment (GFE)

1. Tank, bladder, 500-gal water LIN* NA, 1 each.

2. Pump, centrifugal, GED, 125-gpm, LIN P92030, 1 each.

3. Filter assembly, diatomite, 420-gph, LIN NA, 2 each.

*LIN = Line Item Number.

4. Tank, fabric, collapsible, 1500-gal water, LIN V14881, 3 each.

5. Hose assembly, $1\frac{1}{2}$ in. - $11\frac{1}{2}$ NPSH*, 10 ft, 7 each.

6. Hose assembly, rubber water, braided, 1-in., $11\frac{1}{2}$ NPSH, 10 ft, 4 each.

7. Hose assembly, rubber water, braided, $1\frac{1}{4}$-in., $11\frac{1}{2}$ NPSH, 10 ft, 2 each.

8. Hose, textile fiber, rubber-lined, 300 psi, 1 in., $11\frac{1}{2}$ NPSH, 25 ft, 1 each.

9. Valve, plug, three-way selector, $1\frac{1}{2}$ in, NPT**, 1 each.

10. Valve, flow control, orifice-type, 3/4 inch-14 NPT, 8 gpm, 2 each.

11. Nipple, pipe: brass, 1-in.-diameter, 2 in. long, 2 each.

12. Tee, pipe: brass, $1\frac{1}{2}$-in., 1 each.

13. Nipple, pipe: brass, $1\frac{1}{2}$-in.-diameter, $2\frac{1}{2}$ in. long, 2 each.

14. Valve, gate: bronze, $1\frac{1}{2}$ in. $11\frac{1}{2}$ NPT, 2 each.

15. Adapter, straight, pipe to hose: $1\frac{1}{2}$ in., $11\frac{1}{2}$ NPT ext., $1\frac{1}{2}$ inch $11\frac{1}{2}$ NPSH, 2 each.

16. Float, ball-type: plastic, 8-in. diameter, 3 each.

17. Generator, 3-KW, 60-Hz, military standard, 1 each.

*NPSH = National Pipe Straight Hose.
**NPT = National Pipe Threads.

SECTION II: JOB TASK ANALYSIS SUMMARY

PERSONNEL PLANNING DATA

Task frequencies listed herein are predicted values of task occurrence per mission based on an assumed mission length of 10 days and an operating schedule of 20 hours per day (one operator per shift three shifts per day). Table B1 is an example of personnel planning data.

Total man-minutes identified in the task schedule include productive time per task only; nonproductive time (i.e., time spent waiting for mixing, sedimentation, etc.) is not included.

SECTION III: TRAINING ANALYSIS SUMMARY

COURSE TITLE: FIELD SHOWER WASTEWATER RECYCLING SYSTEM
OPERATOR COURSE

COURSE OBJECTIVE:

To train laundry and bath specialists (MOS 57E) to perform the following tasks at a field operating site:

a. Install the Field Shower Wastewater Recycling System (FSWRS) to a fully operational condition in not more than 1 hour.

b. Operate the FSWRS to renovate wastewater from field bath unit(s) such that the renovated water can be continuously recycled by the field unit(s).

c. Disassemble and stow the FSWRS in accordance with TM ____________.

d. Additional details are in the Job Task Analysis Summary (Table B2) and the Job Data Worksheet (Table B3).

Table B1

Personnel Planning Data

FIELD SHOWER WASTEWATER RECYCLING SYSTEM
Nomenclature

Part Number

22 November 1985
Date

	Operation/ Maintenance						Personnel					Elapsed Time (Minutes)					Task Schedule (Minutes)	
			Maintenance			Rating	MOS/	No. Pers by Skill Level				B	I	A	Total	Fre-quency	Unsched.	Sched.
TASK	OPER	O	F(DS)	H(GS)	D	(Navy)	AFSV	B	I	A	Total							
1.1.1	X						57E	1			1	30			30	1		30
1.1.2	X						57E	1			1	30			30	1		30
1.1.3	X						57E	1			1	10			10	1		10
1.2.1	X						57E	2			2	5			5	1		10
1.2.2	X						57E	2			2	5			5	1		10
1.2.3	X						57E	2			2	15			15	1		30
1.2.4	X						57E	2			2	10			10	1		20
1.2.5	X						57E	2			2	10			10	1		20
1.2.6	X						57E	2			2	5			5	1		10
1.2.7	X						57E	2			2	10			10	1		20
1.3.1	X						57E	1			1	5			5	180		5
1.3.2	X						57E	1			1	30			30	60		30
1.3.3	X						57E	1			1	30			30	60		30
1.3.4	X						57E	1			1	20			20	60		20
1.3.5	X						57E	1			1	30			30	10		30
1.4.1	X						57E	2			2	45			45	1		90
1.4.2	X						57E	2			2	15			15	1		30

Note: OPER = Operator; F(DS) = Field (Direct Support); H(GS) = Heavy (General Support); D = Depot; B = Basic; I = Intermediate; A = Advanced.

Table B2

Job Task Analysis Summary

Nomenclature FIELD SHOWER WASTEWATER RECYCLING SYSTEM Date November 1985

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.1.1	Clear operating site	1	Remove loose rocks and debris from the operating site.	1. Ax 2. Saw
		2	Cut and remove bushes and trees, as necessary, from the operating site.	
1.1.2	Level equipment positions.	1	Using a pick and shovel, level ground in the selected places where the wastewater, treatment, and holding tanks will be located.	1. Pick 2. Shovel
1.1.3	Excavate disposal sump.	1	Using a pick and shovel, dig a hole about 2 ft deep and 2 ft in diameter. Note: The disposal sump should be located within 10 ft of each of the two treatment tanks.	1. Pick 2. Shovel
1.2.1	Install wastewater collection tank	1	Place wastewater collection tank on the ground in its prepared location.	1. Bladder tank, 500 gal
		2	Connect hose from shower unit discharge to wastewater collection tank inlet.	2. Hose assembly, 1-1/2 in. 1/2 NPSH, 10 ft long

Table B2 (Cont'd)

Nomenclature FIELD SHOWER WASTEWATER RECYCLING SYSTEM — Date November 1985

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.2.2	Install wastewater transfer pump	1	Place transfer pump in its operating position.	1. Transfer pump
		2	Connect hose between wastewater collection tank outlet and transfer pump inlet.	2. Hose assembly 1-1/2 in. 11-1/2 NPSH, 10 ft long, 2 each
		3	Add fuel to transfer pump fuel tank.	3. Fuel for transfer pump
		4	Connect 20 ft of hose to pump discharge.	4. Hose assembly, rubber, water, braided. 1 in. 11-1/2 NPSH, 10 ft long Note: Above items are part of wastewater treatment kit. 4610-01-023-4536 (SC 4610-97-CL-E14)

Table B2 (Cont'd)

Nomenclature FIELD SHOWER WASTEWATER RECYCLING SYSTEM — Date November 1985

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.2.3	Install wastewater treatment tanks	1	Position tank in its prepared location.	1. Tank, fabric, collapsible, nylon, water, 1500-gal, 2 each
		2	Install stakes.	2. Hose assembly, 1-1/2-in. 11-1/2 NPSH, 10 ft long, 3 each
		3	Insert wooden staves.	
		4	Install guy ropes.	
		5	Repeat for second tank.	3. Tee, pipe, brass, 1-1/2 in., 1 each
		6	Connect hoses, gate valves, and tee between tanks.	
		7	Connect hose between tee and transfer pump inlet.	4. Nipple, pipe, brass, 1-1/2 in. diameter 2-1/2 in. long, 2 each
				5. Valve, gate, bronze 1-1/2 in., 11-1/2 NPT, 2 each
				6. Adapter, straight, pipe to hose, 1-1/2 in., 11-1/2 NPT ext., 1 1/2 in., 11-1/2 NPSH ext., 2 each
				Note: Above items are part of laundry wastewater treatment kit, 4610-01-023-4536 (SC 4610-97-CL-E14).

Table B2 (Cont'd)

Nomenclature FIELD SHOWER WASTEWATER RECYCLING SYSTEM　　Date November 1985

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.2.4	Install filter units	1	Place filter unit in its operating position.	1. Filter unit, diatomaceous earth, 420 gph, 2 each
		2	Connect 20 ft of suction hose to filter unit.	2. Hose assembly, rubber, water, braided, 1 in. 11-1/2 NPSH, 10 ft long, 4 each
		3	Connect float to other end of suction hose.	
		4	Place suction hose and float into one of the treatment tanks.	3. Float, ball-type, plastic, 8-in. diameter, 2 each
		5	Install pipe nipple into filter.	
		6	Install flow control valve onto pipe nipple.	4. Nipple, pipe, brass 1-in. diameter, 2 in. long, 2 each
		7	Repeat steps 1 through 6 for second filter unit.	5. Valve, flow control, orifice type, 1 NPT, 8 gpm, with bushings. 2 each

Table B2 (Cont'd)

Nomenclature FIELD SHOWER WASTEWATER RECYCLING SYSTEM Date November 1985

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.2.5	Install shower water storage tank	1	Position tank in its prepared location.	1. Tank, fabric, collapsible, nylon, water, 1500-gal
		2	Install stakes.	2. Hose, textile fiber, rubber-lined, 1-in. 11-1/2 NPSH, 25 ft long
		3	Insert wooden staves.	
		4	Install guy ropes.	
		5	Connect hose between flow control valve outlet and tank (place hose outlet over top of 500-gal tank).	
1.2.6	Install bath unit pump	1	Place pump in its operating position.	1. Bath unit pump and hose (part of field bath unit)
		2	Connect suction hose to pump inlet.	2. Float, ball-type, plastic, 8-in. diameter
		3	Connect float ball to inlet end of suction hose and place in shower water storage tank.	
		4	Connect discharge hose between pump discharge and bath unit inlet.	

Table B2 (Cont'd)

Nomenclature FIELD SHOWER WASTEWATER RECYCLING SYSTEM

Date November 1985

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.2.7	Install generator	1	Place generator in its operating position.	1. Generator set, 3-kW, 60-Hz, gasoline engine-driven
		2	Drive ground rod into ground.	2. Power cable, 2 each (part of filter units)
		3	Connect ground cable between generator set and ground rod.	3. Ground rod
		4	Connect power cable between generator and filter units.	4. Ground cable
		5	Add fuel to generator set fuel tank.	5. Sledgehammer
				6. Ground rod clamp
				7. Adjustable wrench

Table B2 (Cont'd)

Nomenclature FIELD SHOWER WASTEWATER RECYCLING SYSTEM

Date November 1985

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.3.1	Transfer wastewater	1	Open wastewater collection tank discharge valve.	
		2	Set three-way plug valve to transfer position.	
		3	Start the transfer pump.	
		4	When the transfer is complete, stop the transfer pump and close the wastewater collection tank discharge valve.	

Table B2 (Cont'd)

Nomenclature FIELD SHOWER WASTEWATER RECYCLING SYSTEM Date November 1985

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.3.2	Chemically treat wastewater	1	Measure pH of wastewater with litmus paper.	1. 24 lbs of powdered activated carbon
		2	Adjust pH of wastewater to 7 ± 1.	2. 300 mL of sulfuric acid or 100 mL of dry sodium carbonate
		3	Add powdered carbon to the treatment tank.	3. 225 mL of cationic polyelectrolyte (Type I Polymer)
		4	Add Type I polymer to treatment tank.	4. Three g of anionic polyelectrolyte (Type II Polymer)
		5	Stir with paddle.	
		6	Set the three-way plug valve to the "recirculate" position.	5. Timer (30-minute or greater capacity)
		7	Start the transfer pump.	6. Litmus paper Note: Timer not in current equipment listing for Pollution Abatement Kit
		8	Wait 30 minutes.	
		9	Stop the transfer pump.	
		10	Add Type II polymer.	7. Stirring paddle
		11	Stir with paddle.	
		12	Allow floc to settle.	

Table B2 (Cont'd)

Nomenclature FIELD SHOWER WASTEWATER RECYCLING SYSTEM — Date November 1985

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.3.3	Filter treated water	1	Start generator.	1. Diatomaceous earth
		2	Mix diatomite slurry in bucket; pour into filter shell.	2. Bulls-eye turbidimeter
		3	Start filter unit pump.	
		4	Precoat filter elements.	
		5	Operate filter water to 40 psi.	
		6	Check turbidity of filtered water using bulls-eye turbidimeter.	
		7	Backwash filter; stop filter unit pump.	
		8	Stop generator.	

Table B2 (Cont'd)

Nomenclature FIELD SHOWER WASTEWATER RECYCLING SYSTEM — Date November 1985

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.3.4	Chemically treat filtered water	1	Measure pH of filtered water using color comparator and pH disks.	1. Calcium hypochlorite
		2	Adjust pH of filtered water to 7.0 ± 0.5.	2. Wooden paddle
		3	Add calcium hypochlorite to water in storage tank.	3. Color comparator with pH and chlorine disks
		4	Stir.	4. Sulfuric acid
		5	Measure free residual chlorine.	5. Sodium carbonate
1.3.5	Dispose of accumulated sludge	1	Scoop sludge from bottom of treatment tank.	1. Sludge scoop
		2	Dump sludge into disposal sump.	

Table B2 (Cont'd)

Nomenclature FIELD SHOWER WASTEWATER RECYCLING SYSTEM — Date November 1985

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.4.1	Disassemble Field Shower Wastewater Recycling System	1	Drain and rinse wastewater treatment tanks.	
		2	Shut down generator.	
		3	Disconnect electric cables.	
		4	Drain wastewater collection tank.	
		5	Drain shower water storage tank.	
		6	Remove guy ropes, stakes and wooden staves from collapsible tanks.	
		7	Collapse tanks.	
		8	Disconnect and drain water from all hoses, valves, and fittings.	
1.4.2	Stow Field Shower Waste-Water Recycling System	1	Roll up hoses.	1. Storage bags
		2	Place all items in their respective storage bags.	2. Truck/trailer
		3	Load equipment onto truck/trailer.	

Table B3

Job Data Worksheet

JOB TITLE OPERATOR MOS 57E PAGE NO.___

DUTY/CODE LAUNDRY & BATH SPECIALIST LEVEL DATE NOVEMBER 1985

Item Code	Task, Elements JPM	Conditions	Initiating Cues	Standards	Notes
1.1.1	Clear operating site	In a field environment	Given an unimproved operating site	Clear the site of rocks, debris and vegetation in accordance with para ___, TM .	Provide ax, saw, and TM.
1.1.2	Level equipment positions	In a field environment	Given a cleared operating site	Level the ground position for the collection, treatment, and storage tanks in accordance with para __, TM _.	Provide pick, shovel, and TM.
1.1.3	Excavate disposal sump	In a field environment	Given a cleared and leveled operating site	Excavate a disposal sump in accordance with para _, TM ___.	Provide pick, shovel, and TM.

Table B3 (Cont'd)

JOB TITLE OPERATOR ______ MOS 57E ______ PAGE NO. ______

DUTY/CODE LAUNDRY & BATH SPECIALIST ______ LEVEL ______ DATE NOVEMBER 1985

Item Code	Task, Elements JPM	Conditions	Initiating Cues	Standards	Notes
1.2.1	Install waste-water collection tank	At a field operating site	Given a field shower wastewater recycling system and a prepared operating site	Install the wastewater collection tank in accordance with para __, TM __.	Provide wastewater collection tanks, inlet hose assembly, and TM.
1.2.2	Install waste-water transfer pump	At a field operating site	Given a field shower wastewater recycling system with wastewater collection tank installed	Install the wastewater transfer pump in accordance with para __, TM __.	Provide transfer pump, hoses, fuel, and TM.
1.2.3	Install waste-water treatment tanks	At a field operating site	Given a field shower wastewater recycling system with the wastewater transfer pump installed	Install the waste-water treatment tanks in accordance with para __, TM __.	Provide treatment tanks, hoses, valves, fittings, and TM.
1.2.4	Install filter units	At a field operating site	Given a field shower wastewater recycling system with the waste-water treatment tanks installed	Install the filter units in accordance with para __, TM __.	Provide filter units, hoses, nipples, float valves, and TM.

Table B3 (Cont'd)

JOB TITLE OPERATOR MOS 57E PAGE NO. ____

DUTY/CODE LAUNDRY & BATH SPECIALIST LEVEL ____ DATE NOVEMBER 1985

Item Code	Task, Elements JPM	Conditions	Initiating Cues	Standards	Notes
1.2.5	Install shower water storage tank	At a field operating site	Given a field shower wastewater recycling system with the filter units installed.	Install the shower water storage tank in accordance with para __, TM __.	Provide tank, hose, and TM.
1.2.6	Install bath unit pump	At a field operating site	Given a field shower wastewater recycling system with the shower water storage tank installed.	Install the bath unit pump in accordance with para __, TM __.	Provide pump, hoses, float, and TM.
1.2.7	Install generator	At a field operating site	Given a field shower wastewater recycling system with all plumbing installed.	Install the generator in accordance with para __, TM __.	Provide generator power cables, ground rod, ground rod clamp, ground cable, adjustable wrench, sledgehammer, and TM.

Table B3 (Cont'd)

JOB TITLE OPERATOR MOS 57E PAGE NO.

DUTY/CODE LAUNDRY & BATH SPECIALIST LEVEL DATE NOVEMBER 1985

Item Code	Task, Elements JPM	Conditions	Initiating Cues	Standards	Notes
1.3.1	Transfer wastewater	At a field operating site	Given an operational field shower wastewater recycling system with a full wastewater collection tank	Transfer the wastewater to the treatment tank in accordance with para __, TM __.	
1.3.2	Chemically treat wastewater	At a field operating site	Given an operational field shower wastewater recycling system with a full treatment tank	Chemically treat the wastewater in accordance with para __, TM __.	Provide powdered activated carbon, cationic polyelectrolyte, anionic polyelectrolyte, sulfuric acid, sodium carbonate, stirring paddle, timer, and TM.
1.3.3	Filter treated water	At a field operating site	Given an operational field shower wastewater recycling system with treated water in one or both treatment tanks	Filter the treated wastewater in accordance with para __, TM __.	Provide diatomaceous earth, bucket, bulls-eye turbidimeter, measure, and TM.

Table B3 (Cont'd)

JOB TITLE OPERATOR ________ MOS 57E ________ PAGE NO. ________

DUTY/CODE LAUNDRY & BATH SPECIALIST ________ LEVEL ________ DATE NOVEMBER 1985

Item Code	Task, Elements JPM	Conditions	Initiating Cues	Standards	Notes
1.3.4	Chemically treat filtered water	At a field operating site	Given an operational field shower waste-water recycling system with filt-ered water in the shower tank	Chemically treat filtered water in accordance with para __, TM __.	Provide calcium hypo-chlorite, sulfuric acid, sodium carbonate, measure, wooden paddle, color comparator, and TM.
1.3.5	Dispose of acc-umulated sludge	At a field operating site	Given an operational field shower waste water recycling system with inches of sludge accumulated in either or both of the treatment tanks	*Dispose of the* sludge in accord-ance with para __, TM __.	*Provide sludge scoop* and TM.
1.4.1	Disassemble Field Shower Waste-water Recycling System	At a field operating site	Given an operational field shower waste-water recycling system and orders to prepare the system for movement	Disassemble the system in accordance with para __, TM __.	
1.4.2	Stow Field Shower Wastewater Recy-cling System.	At a field operating site	Given a disassembled field shower waste-water recycling system	Stow the system in accordance with para __, TM __.	Provide storage bags, truck/trailer, and TM.

LESSON TITLE

FIELD SHOWER WASTEWATER RECYCLING SYSTEM INSTALLATION

TERMINAL OBJECTIVE

1.2 At a field operating site, given a disassembled but otherwise fully operable Field Shower Wastewater Recycling System (FSWRS), install the FSWRS to a fully operational condition in accordance with TM ---- with the assistance of one additional soldier, within 1 hour.

	Enabling Objectives	Skills and Knowledge
1.1.1	Clear operating site	
1.1.2	Level equipment positions	
1.1.3	Excavate disposal sump	
1.2.1	Install the wastewater collection tank in accordance with TM ----.	1. Follow written instructions. 2. Interpret mechanical drawings 3. Use common handtools. 4. Identify wastewater collection tank inlet and shower water discharge hose. 5. Assemble threaded plumbing connections.
1.2.2	Install wastewater transfer pump.	1. Follow written instructions 2. Interpret mechanical drawings. 3. Use common handtools. 4. Identify all components of wastewater pumps. 5. Identify pump connections.
1.2.3	Install the wastewater treatment tanks in accordance with TM ---.	1. Follow written instructions. 2. Interpret mechanical drawings. 3. Use common handtools. 4. Identify all components of collapsible fabric water tanks. 5. Identify common plumbing connections.

1.2.4	Install the filter units in accordance with TM ---.	1. Follow written instructions. 2. Interpret mechanical drawings. 3. Use common handtools. 4 Identify all components of the filter unit. 5. Identify common plumbing items. 6. Assemble threaded plumbing connections.
1.2.5	Install the shower water holding tank, in accordance with TM _ .	1. Follow written instructions. 2. Interpret mechanical drawings. 3. Use common handtools. 4. Identify all components of collapsible fabric water tanks. 5. Assemble threaded plumbing connections.

LESSON TITLE

FIELD SHOWER WASTEWATER RECYCLING SYSTEM OPERATION

TERMINAL OBJECTIVE

1.3 At a field operating site, given a fully assembled and operational Field Shower Wastewater Recycling System (FSWRS) and TM __ , operate the FSWRS in accordance with Chapter ___ of the TM to renovate wastewater from field bath unit(s) such that the renovated water can be continuously recycled by the field bath unit(s).

	Enabling Objectives	Skills and Knowledge
1.3.1	Transfer wastewater from collection tank to treatment tanks.	1. Follow written instructions. 2. Use common handtools to make necessary hose connections. 3. Operate gasoline-engine-driven pump. 4. Perform preventive maintenance checks and services on gasoline-engine-driven pump.
1.3.2	Chemically treat the wastewater in accordance with TM __.	1. Follow written instructions. 2. Measure pH of water samples. 3. Measure liquid and dry chemicals. 4. Adjust the pH of water to desired levels. 5. Operate gas-engine-driven pumps. 6. Operate three-way and gate valves. 7. Operate mechanical, electric, or electronic timers.
1.3.3	Filter the treated water in accordance with TM __.	1. Follow written instructions. 2. Operate gas-engine-driven generator sets. 3. Operate mechanical, electric or electronic timers. 4. Measure turbidity of water samples using bulls-eye turbidimeter.

1.3.4 Chemically treat the filtered water in accordance with TM __.

1. Follow written instructions.
2. Measure pH of water samples.
3. Adjust the pH of water to desired levels.
4. Measure dry chemicals.
5. Calculate quantity of calcium hypochlorite required for disinfection.
6. Measure free residual chlorine concentration of water samples.

LESSON TITLE

FIELD SHOWER WASTEWATER RECYCLING SYSTEM PREPARATION FOR MOVEMENT

TERMINAL OBJECTIVE

1.4 At a field operating site, given an assembled Field Shower Wastewater Recycling System (FSWRS), disassemble and stow the FSWRS in accordance with para __, TM __.

Enabling Objectives		Skills and Knowledge
1.4.	Disassemble the Field Shower Wastewater Recycling System (FSWRS) in accordance with TM __.	1. Follow written instructions. 2. Interpret mechanical drawings. 3. Use common handtools. 4. Identify all components of the FSWRS.
1.4.2	Stow the Field Shower Wastewater Recycling System (FSWRS) in accordance with TM __.	1. Follow written instructions. 2. Interpret mechanical drawings. 3. Identify all components of the FSWRS.

SECTION IV: MANPOWER SUMMARY

A. Installation

The FSWRS can be installed in 1 hour by two persons (one MOS 57E10 with one helper, and one MOS nonspecific).

B. Operation

All operator tasks for the FSWRS can be performed by one operator (MOS 57E10). An operating crew of three (MOS 57E10) would be required for a 20-hour-per-day operating schedule. The FSWRS operators would be supervised by the Bath Team Supervisor.

C. Maintenance

All FSWRS components are currently in the Army inventory within various other systems. Maintenance requirements for these components are already established and therefore were not included in this report.

TASK LIST

1.1 SITE PREPARATION

- 1.1.1 Clear Operating Site
- 1.1.2 Level Equipment Positions
- 1.1.3 Excavate Disposal Sump

1.2 INSTALLATION

- 1.2.1 Install Wastewater Collection Tank
- 1.2.2 Install Wastewater Transfer Pump
- 1.2.3 Install Wastewater Treatment Tanks
- 1.2.4 Install Filter Units
- 1.2.5 Install Bath Water Storage Tank
- 1.2.6 Install Bath Unit Pump
- 1.2.7 Install Generator

1.3 OPERATION

- 1.3.1 Transfer Wastewater
- 1.3.2 Chemically Treat Wastewater
- 1.3.3 Filter Treated Water (and Check Turbidity)
- 1.3.4 Chemically Treat Filtered Water (pH, Chlorination)
- 1.3.5 Dispose of Accumulated Sludge

1.4 PREPARATION FOR MOVEMENT

- 1.4.1 Disassemble Field Shower Wastewater Recycling System
- 1.4.2 Stow Field Shower Wastewater Recycling System

APPENDIX C:

EXCERPT FROM TABLE OF ORGANIZATION AND EQUIPMENT CLOTHING EXCHANGE AND BATH SERVICE TEAM (TOE 10520H5FF)

TABLE OF ORGANIZATION AND EQUIPMENT
TOE 10520H5FF
CHANGE
CLOTHING EXCH/BATH SERVICE

HEADQUARTERS DEPARTMENT OF THE ARMY

SECTION II

STRENGTH LEVELS

PARA	LINE/ LIN	CHG NO	ERC	DESCRIPTION	GRADE	MOS	BR	DCPC 1	ASI/RMKS 2	3	4	1	2	3	AUG A	TYPE B	CADRE C
01				CLO EXCH & BATH SVC													
	01	03		DELETE													
	02	03		BATH SPECIALIST	E 4	57E10		P2				1					
	03	07		DELETE													
	04	09		BATH SPECIALIST	E 3	57E10		P2	01			1					
	05	09		TEAM CHIEF	E-5	57E20	NC	P2				1					
				PARA TOTAL								3					
				SRC TOTAL								3					
01	B43663	04	A	BATH UNIT PORTABLE: GED 8 SH LESS POWER								1					
	B49272	04	B	BAYONET-KNIFE: W/SCABBARD FOR M16A1 RIFLE						300		3					
	C00601	08	B	CHARGER RADIAC DETECTOR: PP-4370/PD								1					
	E00533	08		DELETED													
	J45699	04	A	GEN ST GAS ENG: 3KW 60HZ 1-3PH 120/240 120/208V SKD TAC UTILITY								1					
	K24862	04	B	HEATER DUCT TYPE PTBL: GAS 250000 BTU WHL MTD								1					
	M11895	04	B	MASK CBR: PROTECTIVE FIELD								3					
	Q19339	04	B	RADIAC SET: AN/PDR-27								1					
	Q20935	08		DELETED													
	Q21483	04	B	RADIACMETER: IM-174/PD								1					
	R21551	08	B	RADIACMETER: IM-185/UD								2					
	R94977	04	B	RIFLE 5.56 MILLIMETER:								3					
	W95811	04	B	TRAILER CARGO: 1 1/2 TON 2 WHEEL W/E								1					
	X40009	04	B	TRUCK CARGO: 2 1/2 TON 6 x 6 W/E								1					

APPENDIX D:

USAMBRDL MEMORANDUM: GC/MS ANALYSES OF WATER SAMPLES FROM V. J. CICCONE ASSOCIATES/VIRGINIA MILITARY INSTITUTE RESEARCH LABORATORY SHOWER WATER RECYCLING TESTS

August 20, 1985

MEMORANDUM FOR DR. WINIFRED CURLEY

SUBJECT: GC/MS Analyses of Water Samples from VJCA/VMIRL Shower Water Recycling Tests

Background

Reference: Letter from CDR., USAMBRDL, to Dr. Ed Smith, U.S. Army Construction Engineering Research Laboratory (CERL-EN), dated 23 Jun 85.

Summary of Results

Two batches of samples were received: batch one consisted of 8 recycles, batch two of 11 recycles. Samples were collected at three stages in each recycle: (1) shower effluent, untreated, (2) treated and filtered water, before chlorination, (3) treated and filtered water, after chlorination.

For batch one, each of the three samples collected at recycle 1, recycle 4, and recycle 8 were analyzed and the results compared with those of the source water. The major organics found in the source water were phthalates, in addition to traces of heptadeconoic acid and higher fatty acids. The three untreated shower effluents were all similar and showed a heavy burden of fatty acids (mainly even-numbered) ranging from C_8 to C_{18}, and hydrocarbons. In contrast, the treated water samples were very clean and very similar in trace organic content to the source water. Concentrations of individual trace organics were estimated to range from <0.1 ppb to 10 ppb, with the majority below 1 ppb. No new trace organics were found in the treated water samples after chlorination. The only chlorine-containing compounds found in any of the samples were shown to be impurities present in the chloroform used for liquid/liquid extraction of the trace organics. The total trace organic content of the treated waters appeared to decrease with increasing number of recycles: recycle 1 was equivalent to source water, recycle 4 was somewhat cleaner, and recycle 8 was cleaner still.

In view of these results, only two rather than three sets of samples--those from recycle 3 and recycle 11--were analyzed from batch two. A very similar pattern was observed. No new trace organics were found in the treated water samples after chlorination, and the total trace organic content appeared to decrease between recycle 3 and recycle 11.

Experimental Results

GC/MS analyses were performed in electron impact (EI) mode at 70 eV with a Hewlett Packard 5985B-RTE VI system (database of 70,000 mass spectra) having a 25-m, fused-silica, DB-5 capillary column interfaced directly to the source. Source temperature was 200°C, and the column was programmed from 100° to 250°C at 20°C/minute with an initial hold of 2 minutes and a total run time of 15 minutes. Under these conditions, retention times observed for octanoic and octadecanoic acids were 3.5 minutes and 9.8 minutes, respectively.

The untreated shower effluent samples were allowed to settle, and 10 mL of each supernatant were removed by pipette, transferred to a beaker, and stirred to saturation with sodium chloride. The solution was then extracted with two 2-mL portions of chloroform, and the dried (magnesium sulfate) extracts were rotary-evaporated below room temperature just long enough to remove the chloroform. The residue was reconstituted in 100 μL of acetone and 1 μL was injected for analysis. The procedures for source water and the treated water samples were similar except that for the treated water, a 20 mL-portion was used, and the residue after evaporation of chloroform was reconstituted in 2 μL of acetone and the whole injected.

Initially, solid phase extraction (SPE) was evaluated as a possible alternative to the classic liquid/liquid extraction (L/LE) of the trace organics. The results in both cases were very similar, but SPE proved less attractive due to the long periods of time (> 1 hr) required for complete removal of water from the extraction column. Chloroform was chosen for L/LE because it contained fewer volatile impurities than did the available methylene chloride.

Conclusion

These determinations have shown that the treatment process yielded water with a trace organic content very similar to that of source water. No new trace organics were found in the treated water samples before or after chlorination, and the total trace organic content appeared to decrease with increasing number of recycles. It should be emphasized that the observed "cleanness" of the treated samples by GC/MS relates only to content of volatile trace organics.

Elizabeth P. Burrows, PhD.
Research Chemist

CF:

Dr. Ed Smith, U.S. Army Construction Engineering Research Laboratory
Champaign, IL

Dr. Stephen Schaub, USAMBRDL

LIST OF ABBREVIATIONS

AR	Army Regulation
DPD	N,N diethyl-p-phenylenediamine
FLWRS	Field Laundry Wastewater Recycling System
FSWRS	Field Shower Wastewater Recycling System
gal	gallon
GC/MS	gas chromatography/mass spectroscopy
mL	milliliter
MOS	Military Occupational Specialty
NBC	Nuclear, Biological, and Chemical
NTU	Nephelometric Turbidity Unit
OTSG	Office of the Surgeon General
PAC	Powdered Activated Carbon
POI	Program of Instruction
ROWPU	Reverse Osmosis Water Purification Unit
TRADOC	Training and Doctrine Command
USA-CERL	U.S. Army Construction Engineering Research Laboratory
VMI	Virginia Military Institute
VOC	Volatile Organic Compound
WQAS	Water Quality Analysis Set
WRMAG	Water Resource Management Action Group

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